

SWITCHING MEDIA CONVERTER AND RING TYPE WAVELENGTH  
DIVISION MULTIPLEXING PASSIVE OPTICAL NETWORK SYSTEM USING THE  
SAME

5 BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a wavelength division  
multiplexing (WDM) passive optical network (PON) system, and  
10 more particularly to a ring type WDM PON system using the same  
wavelength for forward and backward channels while  
inexpensively implementing a redundancy function, and a  
switching media converter usable in the ring type WDM PON  
system.

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Description of the Related Art

A WDM system is known as a system in which different  
wavelengths are assigned to respective subscribers by a  
central office (CO) so that the central office can  
20 simultaneously transmit data to the subscribers. Respective  
subscribers can transmit data, using different wavelengths  
assigned thereto. This system has advantages in that it can  
provide a large quantity of information to each subscriber  
while maintaining a high security and easily achieving an  
25 improvement in performance.

Also, a PON is known which has an architecture based on an optical network. In such a PON, an optical line termination (OLT) can be connected with a plurality of optical network units (ONUs) via an optical cable, using a passive optical cross-connect element. In this PON, data from a central office is transmitted to a remote node (RN) via a trunk fiber, and then transmitted to respective subscribers via distribution fibers by a passive optical cross-connect element provided at the remote node. That is, the connection between the central office and the remote node installed in an area adjacent to subscribers is achieved using a trunk fiber, whereas the connection between the remote node and each ONU is achieved using a distribution fiber. In accordance with such a connection structure, it is possible to reduce the cable installation costs, as compared to the case in which an optical cable is installed between the central office and each subscriber.

Meanwhile, the physical topology of an optical network is selected from a ring type, a bus type, and a star type, upon designing the optical network in accordance with an application of the optical network. The concept corresponding to the physical topology of an optical network is a logical topology. This logical topology is also selected from a ring type, a bus type, and a star type in accordance the physical and logical connection states of constitutive elements in the

optical network. As compared to other types, the ring type topology has been recognized as exhibiting a satisfactory reliability in backbone architecture and networks because it can perform a self-healing function even when system failure occurs due to any disaster or accident.

Early developed WDM ring architectures were unidirectional. In order to implement a bi-directional WDM ring architecture, therefore, it is necessary to use a double fiber. Recently, research on single fiber bi-directional ring networks has been conducted. In accordance with this research, single fiber bi-directional ring networks are implemented using bi-directional add/drop modules (B-ADMs) of a new type (disclosed in, for example, C. H. KIM et al., "Bi-directional WDM Self-Healing Ring Network Based on Simple Bi-directional Add/Drop Amplifier Modules"; and Y. Zhao et al., "A Novel Bi-directional Add/Drop Module for Single Fiber Bi-directional Self-Healing Wavelength Division Multiplexed Ring Networks").

Conventional systems having a self-healing function use a double fiber ring architecture. When system failure occurs due to fiber breakage in such a system, the path defined between nodes at opposite ends of the switched fiber in the system is bypassed over the self-healing fiber by an active element. Thus, the switched system can be self-healed. However, this self-healing system has a problem of an increase

in the fiber installation costs caused by the double fiber ring architecture.

Also, the above mentioned single fiber bi-directional ring networks using B-ADMs are complex and expensive while having a problem in that new type optical elements should be used.

Meanwhile, use of a system using an Ethernet is increasing in most networks because the system can be inexpensively implemented while being compatible with conventional Internet traffic. However, such an Ethernet system has not been practically applied to backbone networks because it does not have a self-healing function coping with disaster or other network disabling statuses, so that it does not have a verified reliance.

As a technique for solving the above mentioned problems, there is a "ring type WDM PON system" disclosed in the Korean Patent Application No. 2002-76191 filed in the name of the applicant in the Korean Intellectual Property Office. As shown in Fig. 1, the disclosed "ring type WDM PON system" includes a central office CO including a first multiplexer/demultiplexer MUX1 adapted to perform a multiplexing/demultiplexing operation for normal signals to be used in a normal state, and a second multiplexer/demultiplexer MUX2 adapted to perform a multiplexing/demultiplexing operation for self-healing signals to be used for a self-

healing purpose. Each multiplexer/demultiplexer performs functions of generating optical signals of N different wavelengths, multiplexing the optical signals, and transmitting the resultant multiplexed optical signal to remote nodes RN via a trunk fiber, while demultiplexing a multiplexed signal received from the remote nodes RN.

As shown in Fig. 1, the central office CO includes, for each wavelength, two transmitting/receiving units each including a transmitter Tx and a receiver Rx, in order to implement a general redundancy. One transmitting/receiving unit, for example, the first transmitting/receiving unit including a transmitter Tx1 and a receiver Rx1, is connected to one multiplexer/demultiplexer, for example, the first multiplexer/demultiplexer MUX1, for a normal operation, whereas the other transmitting/receiving unit, for example, the second transmitting/receiving unit including a transmitter Tx2 and a receiver Rx2, is connected to the other multiplexer/demultiplexer, for example, the second multiplexer/demultiplexer MUX2, for a redundancy purpose.

However, the above mentioned ring type WDM PON system has a drawback in that the architecture of the central office CO is complex because two transmitting/receiving modules for each wavelength and two multiplexers/demultiplexers are used to provide a redundancy for coping with fiber breakage or failure of a laser diode (LD) (corresponding to a transmitter)

or photodiode (PD) (corresponding to a receiver) associated with a particular channel. Accordingly, it is required to develop a system capable of solving the problem.

5 Where the above mentioned ring type network architecture is configured to have a redundancy for all nodes, there may be problems in terms of costs and functions. To this end, it is necessary to develop a system configured taking into consideration such problems. It is also necessary to develop a system in which even when fiber breakage occurs at a node  
10 provided with a redundancy function, it can be rapidly detected by a lower-order layer of the node.

#### SUMMARY OF THE INVENTION

15 Therefore, an object of the present invention is to provide a ring type WDM PON system using the same wavelength for forward and backward channels, which has a single fiber bi-directional ring architecture, thereby being capable of simplifying the architecture of its central office while  
20 ensuring a desired redundancy.

Another object of the invention is to provide a ring type WDM PON system using the same wavelength for forward and backward channels, which is configured to provide a redundancy for a part of its nodes, taking into consideration the  
25 significance of each node, thereby minimizing the network

construction costs.

Another object of the invention is to provide a ring type WDM PON system using the same wavelength for forward and backward channels, in which fiber breakage occurring at a node provided with a redundancy function can be rapidly detected by a lower-order layer of the node.

In accordance with one aspect, the present invention provides a ring type wavelength division multiplexing passive optical network (WDM PON) system using the same wavelength for forward and backward channels, comprising: a central office including general media converters (MCs) each having a transmitter adapted to convert an electrical signal into an optical signal to be outputted, and a receiver adapted to receive an optical signal having the same wavelength as the output optical signal, and to convert the received optical signal into an electrical signal to be outputted, and a WDM multiplexer/demultiplexer (MUX/DEMUX) for multiplexing optical signals of different wavelengths respectively outputted from the general MCs, and externally outputting the resultant multiplexed optical signal, the WDM MUX/DEMUX also demultiplexing a multiplexed signal, externally inputted thereto, and outputting the resultant demultiplexed signals to respective general MCs; a coupler for transmitting the multiplexed signal outputted from the WDM MUX/DEMUX through two different optical communication lines in a distributed

manner, while transmitting an optical signal received from any one of the optical communication lines to the WDM MUX/DEMUX; the optical communication lines constructing a ring type distribution network through bi-directional add/drop devices each coupled to the optical communication lines; and remote nodes including redundancy MCs respectively coupled to the bi-directional add/drop devices, each of the redundancy MCs functioning to detect a line breakage, and to transmit an optical signal only in a clockwise or counter-clockwise direction in accordance with the result of the detection.

At least one of the remote nodes may further include a 3-port add/drop device coupled to the optical communication lines constructing the ring type distribution network.

Preferably, each of the bi-directional add/drop devices comprises first and second WDM thin film filters having opposite signal travel directions between the optical communication lines. The first WDM thin film filter drops a particular wavelength one of optical signals, received from a first one of the optical communication lines, to a master channel of the redundancy MC coupled to the bi-directional add/drop device, while receiving an optical signal having the same wavelength as the dropped optical signal, and reflecting the received optical signal to the first optical communication line. The second WDM thin film filter drops the particular wavelength one of optical signals, received from a second one



of the optical communication lines, to a slave channel of the redundancy MC, while receiving an optical signal having the same wavelength as the dropped optical signal, and reflecting the received optical signal to the second optical communication line.

Preferably, each of the redundancy MCs comprises: first and second couplers respective connected to the master channel and the slave channel; master and slave transmitting/receiving units respectively connected to the first and second couplers, each of the master and slave transmitting/receiving units functioning to convert an electrical signal into an optical signal, and to transmit the optical signal to the coupler connected thereto, while functioning to convert an optical signal received from the connected optical coupler into an electrical signal, and to output the electrical signal to an optical network unit; a control unit for detecting respective states of the master and slave transmitting/receiving units and a fiber breakage status, thereby activating a selected one of the master and slave transmitting/receiving units to perform transmitting and receiving operations; and interfaces respectively connected to the master and slave transmitting/receiving units, each of the interfaces performing a data interfacing operation between an associated one of the master and slave transmitting/receiving units and the optical network unit.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above objects, and other features and advantages of the present invention will become more apparent after reading the following detailed description when taken in conjunction with the drawings, in which:

Fig. 1 is a schematic diagram illustrating the configuration of a ring type WDM PON system using the same wavelength for forward and backward channels;

Fig. 2 is a schematic diagram illustrating the configuration of a ring type WDM PON system using the same wavelength for forward and backward channels in accordance with an embodiment of the present invention;

Fig. 3 is a schematic diagram illustrating the configuration of a 4-port add/drop device shown in Fig. 2;

Fig. 4 is a schematic diagram illustrating a detailed configuration of a switching media converter for a redundancy purpose shown in Fig. 2;

Fig. 5 is a flow chart illustrating a line switching operation carried out by a central processing unit (CPU) shown in Fig. 4; and

Fig. 6 is a schematic diagram of a ring type WDM PON system using the same wavelength for forward and backward channels in accordance with another embodiment of the present

invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

5           Now, preferred embodiments of the present invention will be described in detail with reference to the annexed drawings. In the following description of the present invention, a detailed description of known functions and configurations incorporated herein will be omitted when it may make the  
10           subject matter of the present invention rather unclear.

          Fig. 2 is a schematic diagram illustrating the configuration of a ring type WDM PON system using the same wavelength for forward and backward channels in accordance with an embodiment of the present invention. Fig. 3 is a  
15           schematic diagram illustrating the configuration of a 4-port add/drop device 120 shown in Fig. 2. Fig. 4 is a schematic diagram illustrating a detailed configuration of a switching media converter 130 for a redundancy purpose shown in Fig. 2.

          Referring to Fig. 2, the ring type WDM PON system  
20           according to the illustrated embodiment of the present invention includes a central office (CO), and bi-directional add/drop devices 120 and redundancy media converters (MCs) 130 connected to the central office via optical communication lines.

25           The central office includes general media converters

(MCs) each having a transmitter TX adapted to convert an electrical signal into an optical signal to be outputted, and a receiver RX adapted to receive an optical signal having the same wavelength as the output optical signal, and convert the received optical signal into an electrical signal to be outputted. The central office also includes a WDM multiplexer/demultiplexer (MUX/DEMUX) 100 for multiplexing optical signals of different wavelengths respectively outputted from the general MCs, and externally outputting the resultant multiplexed optical signal. The WDM MUX/DEMUX 100 also demultiplexes a multiplexed signal, externally inputted thereto, and outputs the resultant demultiplexed signals to respective general MCs. A 3dB coupler is coupled between each general MC and the WDM MUX/DEMUX 100 in the central office. The 3dB coupler also serves as a splitter for distributing the demultiplexed optical signals from the WDM MUX/DEMUX 100 to both the transmitters TX and receivers RX of respective general MCs.

Also, a 3dB coupler 110 is coupled to a signal output stage (also serving as a signal input stage) of the central office. The coupler 110 transmits the multiplexed signal outputted from the WDM MUX/DEMUX 100 through two different optical communication lines (optical fibers) in a distributed manner. The coupler 110 also transmits an optical signal received from any one of the optical communication lines to

the WDM MUX/DEMUX 100.

The reason why the output from the central office is transmitted through two paths in a distributed manner by the coupler 110 is to provide a redundant channel to cope with fiber breakage or failure of the transmitter (LD) or receiver (PD) associated with a particular channel.

The optical communication lines of different transmission directions connected to the coupler 110 construct a ring type distribution network, as shown in Fig. 2. Bi-directional add/drop devices 120 are arranged at appropriate points of the ring type distribution network, respectively, in order to support signals to travel normally in both directions while dropping an optical signal having a wavelength associated with a particular subscriber. In the illustrated embodiment, each bi-directional add/drop device 120 is a bi-directional 4-port add/drop device.

The bi-directional add/drop device 120 includes two WDM elements having opposite signal travel directions between the opposite optical communication lines constructing a ring type distribution network, that is, first and second optical communication lines. That is, the bi-directional add/drop device 120 includes a first WDM thin film filter for dropping a particular wavelength one,  $\lambda_m$ , of optical signals, received from the first optical communication line connected to an input port Com IN Port of the bi-directional add/drop device

120, to a master channel of the associated redundancy MC 130, while receiving an optical signal having the same wavelength as the dropped optical signal, and reflecting the received optical signal to the first optical communication line, and a  
5 second WDM thin film filter for dropping the particular wavelength one,  $\lambda_m$ , of optical signals, received from the second optical communication line connected to another input port Com OUT Port of the bi-directional add/drop device 120, to a slave channel of the associated redundancy MC 130, while  
10 receiving an optical signal having the same wavelength as the dropped optical signal, and reflecting the received optical signal to the second optical communication line.

By virtue of the bi-directional add/drop device 120, the associated remote node can transmit an optical signal received  
15 from an associated ONU in the ring type distribution network in a clockwise or counter-clockwise direction.

Meanwhile, redundancy MCs 130 are coupled to respective bi-directional add/drop devices 120. Each redundancy MC 130 detects fiber breakage, thereby transmitting an optical signal  
20 only in a clockwise or counter-clockwise direction. Each redundancy MC 130 may be directly connected to an associated ONU. Alternatively, the redundancy MC 130 may be connected to the associated ONU via an Ethernet.

Now, the redundancy MCs 130 will be described in more  
25 detail with reference to Fig. 4. As shown in Fig. 4, each

redundancy MC 130 mainly includes a transmitting/receiving unit for a master channel, a transmitting/receiving unit for a slave channel, a central processing unit (CPU) 136, and physical-layer (PHY) chips 135 and 145.

5           3dB couplers are connected to the master and slave channels, respectively. These couplers may be internally arranged in the associated redundancy MC 130. Alternatively, they may be arranged outside the associated redundancy MC 130. It may be assumed that the master channel is connected to a  
10 drop port of the associated bi-directional add/drop device 120 shown in Fig. 3, which may serve as an add port for a backward signal. It may also be assumed that the slave channel is connected to an add port of the associated bi-directional add/drop device 120 shown in Fig. 3. On these assumptions,  
15 the optical signal transmitted through the drop port and master channel is distributed to both the transmitter and receiver for the master channel, that is, an LD 131 and a PD 133. On the other hand, the optical signal outputted from the transmitter for the master channel, that is, the LD 131, is  
20 transmitted to the central office via the coupler and drop port.

The master transmitting/receiving unit for the master channel and slave transmitting/receiving unit for the slave channel include respective LDs 131 and 143, which are light  
25 sources, for their transmitters, and respective LD drivers 132

AND 144 for driving the LDs 131 and 143. The master and slave transmitting/receiving units also include respective PDs 133 and 141, which are light sources, for their receivers, and respective LD drivers for driving the PDs 134 and 142. Each of the master and slave transmitting/receiving units converts an electrical signal into an optical signal, and transmits the optical signal to the coupler connected thereto, while converting an optical signal received from the optical coupler into an electrical signal, and outputting the electrical signal to an associated ONU via an interface 135 or 145.

The CPU 136 controls the whole operation of the associated redundancy MC 130. For example, the CPU 136 detects respective states of the master and slave transmitting/receiving units and a fiber breakage status, based on control program data stored in its internal memory, so as to activate a selected one of the master and slave transmitting/receiving units to perform transmitting and receiving operations. This operation will be described hereinafter with reference to Fig. 5.

Each redundancy MC 130 according to the illustrated embodiment of the present invention further includes the interfaces 135 and 145 respectively connected to the master and slave transmitting/receiving units, and adapted to perform data interfacing operations. For the interfaces 135 and 145, PHY chips may be used. For reference, each redundancy MC 130



may further include a buffer 137 arranged at the rear end of the interface 145 connected to the slave transmitting/receiving unit, and adapted to perform a data buffering operation.

5           Now, the line switching operation carried out by the CPU 136 shown in Fig. 4 will be described in conjunction with Fig. 5.

10           When the system turns on, the CPU 136 of each redundancy MC 130 is switched to its initial state. In the initial state, the CPU 136 sets the master channel to a first channel (Step 200). After the operation of setting the master channel to the first channel, the CPU 136 checks whether or not an alarm is generated (Step 210). The CPU 136 can check generation of an alarm by reading respective states of the master and slave PDs 133 and 141. In the illustrated embodiment of the present invention, it is determined that an alarm has been generated, unless both the LD 131 and PD 133 are in their normal states, as described in the following Table 1. In Table 1, "0" represents a fault or disable state, 15           whereas "1" represents an active or enable state.

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Table 1

MLD State	SLD State	MPD Link	SPD Link	Current State	Remarks
0	0	0	0	Alarm	
0	0	0	1	Alarm	
0	0	1	0	Alarm	
0	0	1	1	Alarm	
0	1	0	0	Alarm	
0	1	0	1	Slave	
0	1	1	0	Alarm	
0	1	1	1	Slave	
1	0	0	0	Alarm	
1	0	0	1	Alarm	
1	0	1	0	Master	Reflection Check
1	0	1	1	Master	
1	1	0	0	Alarm	Disable Both
1	1	0	1	Slave	
1	1	1	0	Master	
1	1	1	1	Master	

Where it is determined, based on the result of the alarm state checking at step 210, that the current state of the system corresponds to an alarm state, the CPU 136 records the

current alarm state in its internal memory (Step 220), and then continuously monitors the state of the system.

If it is determined that the system is not in an alarm state, the CPU 136 then performs a channel switching operation for using the first channel set at step 200 as the current channel (Step 230). Thereafter, the CPU 136 checks whether or not an erroneous event has occurred, while maintaining the current state of the system (Step 240). Where an erroneous event occurs at the current channel under the condition in which the system is not in an alarm state, it is necessary to switch the current channel to a channel other than the current channel. For this channel switching, it is also necessary to perform a procedure for checking whether the erroneous event corresponds to a link error caused by reflection or a system error. For reference, where an optical fiber is broken such that it has a vertical surface at its broken end surface, reflection occurs at the broken end surface, so that an optical signal transmitted from a transmitter through the optical fiber may be returned to the transmitter. As a result, it is impossible to recognize the breakage of the optical fiber. Accordingly, it is necessary to identify an error caused by such reflection.

To this end, when the CPU 136 detects an erroneous event, it determines whether or not the erroneous event corresponds to a system error (Step 250). If no pilot packet

from a remote location is received within a predetermined time, it is determined that a system error has occurred. Where the erroneous event does not correspond to a system error, the CPU 136 proceeds to step 290 to switch the system to a redundancy "ON" state. That is, the CPU 136 disables the current channel, that is, the master channel, while enabling a redundant channel, that is, the slave channel. Thereafter, the CPU 136 returns to step 210.

On the other hand, where it is determined that a system error has occurred, the CPU 136 disables the LD of the current channel, that is, the master LD 131, in order to determine whether or not the system error has been caused by reflection (Step 260). The CPU 136 then checks whether or not the PD of the current channel can be switched to a "link-on" state (Step 270). When the PD of the current channel can be switched to a "link-on" state, the CPU 136 proceeds to step 290 because the system error has not been caused by reflection. At step 290, the CPU 136 switches the system to the redundancy "ON" state. On the other hand, where the PD of the current channel cannot be switched to a "link-on" state, the CPU 136 informs the associated external device of the fact that reflection has occurred at the current channel, because the erroneous event detected at step 240 has been caused by reflection (Step 280). Subsequently, the CPU 136 proceeds to step 290 to switch the system to the redundancy "ON" state, and then returns to step

210.

Thus, the CPU 136 operates to detect fiber breakage, and switches the system to a redundancy "ON" state for use of a redundant channel when it detects fiber breakage. In a normal state, the central office and each remote node can perform normal optical transmission through the master channel. When a failure such as fiber breakage occurs, the CPU 136 included in the redundancy MC 130 of each remote node detects the failure, and switches the system to a redundancy "ON" state. Accordingly, the remote node and central office can perform normal optical transmission, not through the master channel, but through the slave channel.

Meanwhile, in network architectures having a redundancy function, it is important to use a technique for giving a priority to a particular node. In the case of a network architecture configured to have a redundancy for all nodes, there may be problems in terms of costs and functions. Generally, the cost taken to construct a network having a redundancy function is double the cost taken to construct a network having no redundancy function.

To this end, a hybrid type network may be constructed, using 3-port add/drop elements along with 4-port add/drop elements. A more effective network can be constructed by configuring an important node by a bi-directional add/drop element (4-port type) having a self-healing function. An

example of such a network is illustrated in Fig. 6.

Fig. 6 illustrates a schematic diagram of a ring type WDM PON system using the same wavelength for forward and backward channels in accordance with another embodiment of the present invention. Referring to Fig. 6, optical power is transmitted through two lines in a distributed manner by a 3dB coupler at the side of the central office. On the other hand, 4-port add/drop devices and 3-port add/drop devices are arranged in a ring type distribution network. The 3-port add/drop devices are employed for general nodes which are relatively insignificant. In such a network, the 4-port add/drop devices change the optical travel direction between a clockwise direction and a counter-clockwise direction in accordance with fiber breakage, thereby performing a desired optical transmission.

In accordance with another embodiment of the present invention, a system may be constructed in which a bus type network architecture using the same wavelength for forward and backward channels while using 3-port add/drop devices is combined with a ring type network architecture using 4-port add/drop devices. In this system, it is also possible to heal a failure of the line by use of the 4-port add/drop devices, while reducing the system construction costs by using the 3-port add/drop devices for nodes which are relatively insignificant.

As apparent from the above description, the present invention provides a ring type WDM PON system in which a redundancy function is provided to each node, so that the central office of the system can have a simplified architecture. Accordingly, there is an advantage in that the construction costs of the central office can be reduced.

In accordance with the present invention, the network construction costs can be minimized because it is possible to provide a desired redundancy to a part of the nodes, taking into consideration the significance of each node.

In accordance with the present invention, there is another advantage in that fiber breakage occurring at a node can be rapidly detected at a lower-order layer of the node through a media converter having a redundancy function.

Although the preferred embodiments of the invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.